Talk on ACAT2000 Workshop
Fermilab, October 16-20, 2000

CompHEP-PYTHIA interface: integrated package for the collision events generation based on exact matrix elements

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Abstract

CompHEP, as a partonic event generator, and PYTHIA, as a generator of final states of detectable objects, are interfaced. Thus, integrated tool is proposed for simulation of (almost) arbitrary collision processes at the level of detectable particles. Exact (multiparticle) matrix elements, convolution with structure functions, decays, partons hadronization and (optionally) parton shower evolution are basic stages of calculations. The PEVLIB library of event generators for LHC processes is described.

In the widely used generators PYTHIA [1], ISAJET [2] and HERWIG [3] data bases of matrix elements of hard subprocesses are built in. It means that matrix elements are stored as formulas. Furthermore, the matrix element squared $|M|^2$ is represented by means of some function modelling the behaviour of the integrand to get effective Monte-Carlo integration and events generation. Thus, as one can see, mainly $2 \to 2$ subprocesses are included in these data bases.

However, the generation of events with 3, 4 and more bodies in the final states of hard subprocesses is needed for the Tevatron, LHC and future linear collider physics. One can note, in particular, that for such states there is no possibility to construct simple analytical formulae to match singular behaviour of $|M|^2$. Multidimensional phase space (4 dimensions in the 3-body case plus 2 dimensions in case of hadron collisons for convilution with parton distributions, 7+2 dimensions in the 4-body case etc) with untrivial regions corresponding to the singularities of the martrix element leads to complicated symbolic structures. Thus, one needs a new approach to the generation of events at the partonic level.

Partonic level final states with top quarks, Higgs bosons and intermediate vector bosons, like Wtj, ttH, Wbb, $ttbb$ and $tttt$, give practical examples of multidimensional phase space

integration. Then, multiple production of light quarks, gluons, leptons and photons also assumes the evaluation of multiparticle final states if one is interested in effects at high p_T, large invariant masses etc. This problem stands as an important one especially if one should evaluate precisely background processes.

The singular behaviour of the phase space integrand is connected with singular behaviour of propagators in Feynman diagrams: some masses are extremely small (light quarks and leptons) or even zero (gluons and photons), while other masses are of order 100 GeV (M_W, M_Z, M_{top} ...) and collison energies are of hundreds or even thousands of GeV. As a result, huge energy scale difference for the parameters involved produces serious computational problems. One has to regularize the integration measure to smooth the singularities (see, e.g., the discussion in [4]).

To get more partons in final state one can exploit, for example, the QCD *parton-shower* generation. However, this method is good only for soft regimes (small p_T, small angles etc.) and fails in case of hard production of these extra partons.

We propose to use programs created for automatic computation of matrix elements, like CompHEP [5], GRACE [6] and MADGRAPH [7][1] as a tool for generation of data base of hard subprocesses for generators like PYTHIA, ISAJET and HERWIG. In particular, at the step of the evaluation of hard subprocess the phase space grid is adapted to match a singular behaviour of $|M|^2$. So, we develop the *two stage* approach:

1. CompHEP produces cross sections and proper phase space grid. This information is stored in special data base, **PEVLIB**, on the hard disk;
2. events generated by CompHEP are used as an input to generators PYTHIA, ISAJET and HERWIG, for further decaying and hadronization of final partonic states.

In this paper we present the interface to provide an automatic input of CompHEP events to PYTHIA. This interface is under the development still and new options are assumed to be realized, in particular, automatic addition of new events in the data base if the number of events already stored in the existing sample is not enough, and the regeneration of events in case of change of physical parameter set.

Some comments why we propose to separate the *matrix element* and *decay/showers/hadronization* steps of the computations:

- it is easy to automate the interface;
- more flexibility of the computation model is reached:
  - it allows to develop/implement new options in these two steps independently (what corresponds to the standard theoretical approach: at the "matrix element" step quantum effects are evaluated, interference etc, while the second step corresponds to the probability processes);
  - it gives a possibility to input partonic events in different programs for the second step (PYTHIA, ISAJET, HERWIG etc), as well as to create partonic events by different programs, e.g. CompHEP, GRACE, MADGRAPH etc. Of course the standardization of the partonic event files is necessary.

[1] see also programs presented on this Workshop by T. Ohl and C. Papadopoulos [8, 9].

In PYTHIA we use the subroutine PYUPEV to input CompHEP events as an external process.

CompHEP generates events (unweighted in v.41) and writes them to the file

events_N.txt

where N is the number of working session. This is the text file with a header, where information about the subprocess is given, cross section value is written, and some information about the beams is presented (in particular what PDF set was used and what is the QCD scale). Then, events are written (one event - one line).

Then, a command

mixPEV

is used to mix several subprocesses in one event flow according to their relative weight, $\sigma_i/\Sigma_j\sigma_j$, where σ_i is the cross section of the i-th subprocess. This command, mixPEV, randomizes also the position of events from different subprocesses in the final event flow.

As a result of the command mixPEV the file Mixed.PEV with the events from mixed subprocesses is created. In this file headers of all subprocesses contributed are listed in the beginning and then events are written. In the end of each line (event) the information about color flows is given, allowing the user to switch on, for example, Lund Fragmentation Model or other models using color flows in the $N_c \to \infty$ limit. This new option is realized in CompHEP v.41. The event line includes also: the number of subprocess, to which the event belongs, and components of the particles momenta (for in-coming particles only their z-components).

When the command mixPEV is completed the protocol file, Prt.PEV, is created.

The CompHEP code is available from the following addresses:

http://theory.npi.msu.su/comphep/

/afs/cern.ch/cms/physics/COMPHEP/V_41.10.tar.gz

The CompHEP-PYTHIA interface code and command mixPEV are available from:

/afs/cern.ch/cms/physics/PEVLIB/cpyth

where one can find the Fortran code in directory interf45 (for interface with PYTHIA 5.7/JETSET 7.4) and interf46 for interface with PYTHIA v.6.x. The code for the command mixPEV is placed in the directory c_source (the mix.c file).

One should compile Fortran routine from the directory interf46 (or correspondingly from interf45) and link with the PYTHIA object code. For some platforms a user should comment the dummy routine PYUPEV in the original PYTHIA code.

For more details on the PYTHIA switches and other comments we refer the reader to the file main.f, where many comment lines are given with corresponding explanations.

Using the CompHEP-PYTHIA interface we create the PEVLIB library of partonic events for LHC processes. Each process is stored in the subdirectory

/afs/cern.ch/cms/physics/PEVLIB/

In each process subdirectory there is the README file where some details are given concerning the partonic events computed.

Among processes already stored in PEVLIB are the following:

- SingleTop (see details about the number of events generated and subprocesses in the corresponding README file);
- $(H \to \tau^+\tau^-) + 2tagjets$. Here electroweak background events can be found (about 10^5 with Z off-shell and $4 \cdot 10^5$ with Z on-shell), and QCD background (about 65000 events);
- $(H \to b\bar{b}) + t\bar{t}$. Here signal events are generated for $M_H = 100$, 115, 120 and 130 GeV, as well as the events for background processes $t\bar{t}b\bar{b}$ (about 300000 events) and $t\bar{t} + 2jets$ (about 2 millions events);

This work was supported by the INTAS-CERN 99-0377 grant and by the Programme "University of Russia" (grant 990588), and done in the framework of the CPP Collaboration [10].

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